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Interpretation of NASA-STD-3001 Levels of Care for Exploration Medical System Development

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INTRODUCTION

Travelling to cislunar space, asteroids, and other planets, such as Mars, for exploration, will require a higher level of medical care than has been provided in previous space flight programs. Exploration class missions require consideration and planning for the extended duration of the missions and will come with limited telemedicine capabilities, constrained resupply opportunities, and an inability to return a sick or injured crewmember to Earth for definitive care. NASA operational standards, as documented in NASA Standard 3001, Volumes 1 and 2, will be utilized to initiate the design of exploration medical systems of the various design reference missions NASA is considering for future human exploration of space.

The Exploration Medical Capability (ExMC) Element of the Human Research Program (HRP) has developed definitions and example actions for each of the five levels of care documented in the Standard and their associated capabilities. This work was necessary to ensure consistency of interpretation by the multidisciplinary ExMC teams as they embark on creating Concept of Operations (ConOps) for these medical systems. Definitions and example actions are not requirements and are not meant to imply that the medical system for a future program must be capable of managing each action, but instead serve as the starting place for developing a concept of operations and a systematic process for requirements. The examples provided do not imply the capabilities to provide care for all possible medical conditions through to resolution, but merely a starting point. This interpretation provides context for a future program that is developing a medical system to consider medical risk tradeoffs and ethics; assess ability to adhere to terrestrial standards for medical care; and assist with identification and development of tools, resources, and training necessary to support medical operations.

The five levels of care defined in the NASA-STD-3001 are summarized in Table 1 and show a progression of capability.

Table 1 - Levels of Care (Reference NASA-STD-3001, V2, Rev A, Table 13)

Level of Care	Capability
I	Space Motion Sickness, Basic Life Support, First Aid, Private Audio, Anaphylaxis Response
II	Level I + Clinical Diagnostics, Ambulatory Care, Private Video, Private Telemedicine
III	Level II + Limited Advanced Life Support, Trauma Care, Limited Dental Care
IV	Level III + Medical Imaging, Sustainable Advanced Life Support, Limited Surgical, Dental Care
V	Level IV + Autonomous Advanced Life Support and Ambulatory Care, Basic Surgical Care

While NASA-STD-3001 includes a mission-specific location and duration, ExMC realizes that these missions should be used as a guideline to determine what level of care should be considered for each mission. ExMC also understands that each mission is made up of multiple phases that occur in different locations in space and durations and that each phase should be assessed for the level of care most appropriate. For example, two phases of a planetary mission may include transit and surface excursions. While a Level of Care V is the overarching level that is applied to a planetary mission, and is the most likely level during the transit phase, it may not be plausible to consider this level for the surface excursion phase. This phase may align more with a lower level of care depending upon the capabilities expected while in a suit without access to the full capabilities of the transit vehicle. For this reason, ExMC has chosen to leave out the mission-specific descriptions that NASA-STD-3001 relates to each level, but to focus on the raw capability and examples of actions that could be needed for each level, regardless of where the crew is and how long the mission is.

Level of Care I

NASA-STD-3001, Vol 1, describes Level of Care I as follows: "Little perceived threat to health or life exists during training or that portion of the mission where medical intervention would be allowed. The relatively short time and distance to definitive care allows for first-aid implementation without more advanced care. Level of Care One requires a minimum of first-aid capability and implementation plans for follow-on medical support."

The definition and example actions ExMC has chosen in order to examine the differences between the capabilities are listed below in Table 2.

Table 2 - Level of Care I Interpretation

Capability	Definition	Example Actions
Space Motion Sickness	Anticipate, mitigate, and adapt to the acute effects of spaceflight.	- Control over body positioning and workspace - Dispense, administer, and track medications for symptom management - Manage bodily fluids (urine, stool, gastric contents)
Initial Basic Life Support	Provide capability for basic minimum level of care for medical contingencies and emergencies. Recognize need for higher level of care.	- Control over body positioning and workspace **Airway:** - Reposition airway and insert airway adjuncts - Clear obstructed airway with manual maneuvers **Breathing:** - Provide breaths using mouth to mouth **Circulation:** - Control bleeding through direct pressure - Provide chest compressions
First Aid	Provide basic management for common injuries.	- Control minor bleeding through direct pressure - Clean wounds - Cover wounds - Splint extremities - Dispense, administer, and track over the counter (OTC) medications for control of pain and prevention of infection (oral, topical)
Anaphylaxis Response	Recognize symptoms of a severe allergic response and provide a minimum level of care.	- Dispense, administer, and track medications for initial treatment of anaphylaxis (oral, injectable, inhaled)
Private Audio	Private, secure communication, medical monitoring, diagnosis, and care between crew and medical personnel in support of physical, psychological, and spiritual health.	- Private, audio communication - Private, medical device data transmission

Level of Care II

NASA-STD-3001, Vol 1, describes Level of Care II as follows: "A moderate level of risk exists that personnel may experience medical problems during training or that portion of the mission. Preventive strategies shall be used to reduce the risk. Intervention strategies shall be used to reduce the risk to an acceptable level with return to Earth available for more serious illness/injuries. Level of Care Two shall provide for clinical diagnostics and ambulatory care capability in addition to basic life support."

The definition and example actions ExMC has chosen in order to examine the differences between the capabilities are listed below in Table 3.

Table 3 - Level of Care II Interpretation

Capability	Definition	Example Actions
Level of Care I +		"*" indicates augmentation of action from lower level of care
Private Telemedicine	Private, secure communication, medical monitoring, diagnosis, and care between crew and medical personnel in support of physical, psychological, and spiritual health.	- Private, asynchronous audio, video, and text - Private, medical device data transmission with store & forward
Private Video	Private, secure communication, medical monitoring, diagnosis and care between crew and medical personnel in support of physical, psychological, and spiritual health	- Private, video communication - Private, medical device data transmission
Clinical Diagnostics	Laboratory, pharmaceutical resources, and devices that allow an assessment or diagnosis of medical conditions. Resources to support time independent medical decision making based on data.	- Assess body fluids (Blood: chemistries, cell count, markers, gases; Urinalysis) - Assess compartment pressures (intraocular pressure)
Ambulatory Care	Diagnosis and treatment for non-urgent and urgent, short lived medical and psychological conditions. Resources to support medical decision making using data obtained from on-board & telemedicine, limited physical exam, vital signs, and clinical diagnostics.	- Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation) - Perform limited physical exam (visualize, palpate, auscultate) and record results - Dispense, administer, and track medications *for short lived medical conditions (oral, topical, inhaled, injectable) - Drain bladder (continuous/intermittent) - Perform limited psychological exam and counseling

Level of Care III

NASA-STD-3001, Vol 1, describes Level of Care III as follows: "A moderate to high level of risk exists that personnel may experience medical problems during training or that portion of the mission. Preventive strategies shall be used to a greater degree to reduce the overall risk. Intervention strategies shall be used to reduce the risk to an acceptable level, including an increased level of advanced care in the form of medications or equipment to include limited advanced life support, trauma care and limited dental care. The ability to sustain a critically ill or injured patient for any length of time is limited by consumables, training and vehicle constraints."

The definition and example actions ExMC has chosen in order to examine the differences between the capabilities are listed below in Table 4.

Table 4 - Level of Care III Interpretation

Capability	Definition	Example Actions
Level of Care II +		"*" indicates augmentation of action from lower level of care
Limited Advanced Life Support (ALS)	Diagnosis and initial treatment for an emergent medical event. Resources to support medical decision making using data obtained from telemedicine, limited physical exam, vital signs, and clinical diagnostics.	- Control over body positioning and workspace **Airway:** - Reposition airway, insert airway adjuncts *and supraglottic airways - Clear obstructed airway with manual maneuvers - *Suction airway **Breathing:** - Provide breaths using *manual means - *Provide and titrate oxygen via noninvasive/invasive means **Circulation:** - Control bleeding using direct pressure - Provide chest compressions - *Defibrillate using automated device - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation)
Trauma Care	Diagnosis and treatment for conditions caused by trauma (blunt, penetrating, thermal). Resources to support medical decision making using data obtained from telemedicine, limited physical exam, vital signs, and clinical diagnostics.	- Control over body positioning, and workspace **Airway:** - *Stabilize C-spine - Reposition airway, insert airway adjuncts, *and supraglottic airways - Clear obstructed airway with manual maneuvers - *Suction airway **Breathing:** - Provide breaths using *manual means - *Provide and titrate oxygen via noninvasive/invasive means **Circulation:** - Control bleeding using direct pressure, *tourniquet, and simple wound closure - Dispense, administer and track *limited medications for pain control (oral, topical, injectable) - Splint extremities - *Perform secondary & tertiary survey - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation)
Limited Dental Care	Provide temporizing maneuvers to manage dental pain until definitive care is reached.	- Dispense, administer, and track medications *for dental care (oral, topical, injectable) - *Cover fractured tooth with dental material - *Replace lost filling or crown - *Incise dental abscess - *Manage oral secretions during examination and procedures

Level of Care IV

NASA-STD-3001, Vol 1, describes Level of Care IV as follows: "Moderate to high level of potential risk exists that personnel may experience medical problems on orbit. Risk to the mission is greater for medical issues beyond routine ambulatory medicine. Preventive strategies shall be used to a greater degree to reduce the overall risk. The ability to support chronic illness is limited. Intervention strategies shall be used to reduce the risk to an acceptable level, including increasing levels of advanced care in the form of medications, equipment, training, or consumables over and above previous levels. The scope of

medical care available shall be limited or triaged because of availability of supplies, consumables, or mission risk."

The definition and example actions ExMC has chosen in order to examine the differences between the capabilities are listed below in Table 5.

Table 1.5 Level of Care IV Interpretation

Capability	Definition	Example Actions
Level of Care III +		"*" indicates augmentation of action from lower level of care
Sustainable Advanced Life Support (ALS)	Diagnosis and initial critical care treatment for an emergent medical event requiring ALS. Resources to support medical decision making using data obtained from on-board & telemedicine, limited physical exam, vital signs, clinical diagnostics, and medical imaging modality(s).	- *Recognize need for increased level of care - Control over body positioning and workspace **Airway:** - Reposition airway, insert airway adjuncts, supraglottic *and endotracheal airways - Clear obstructed airway with manual maneuvers - Suction airway *and decompress stomach **Breathing:** - Provide breaths using manual *and automated means - Provide and titrate oxygen via noninvasive/invasive means - *Perform needle decompression of chest **Circulation:** - Control bleeding using direct pressure - Provide chest compressions - *ECG rhythm diagnosis - *Defibrillate and pace using manually operated device - *Provide intravenous (IV) or intraosseous (IO) access and fluids - Dispense, administer, and track *limited medications for first line response to arrhythmias per Advanced Cardiac Life Support (ACLS) guidelines (oral, topical, injectable) - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation) - Drain bladder (continuous)
Limited Surgical	Any invasive, operative procedure less than one hour in duration using only local anesthesia. Resources to support medical decision making using data obtained from telemedicine, limited physical exam, vital signs, clinical diagnostics, and medical imaging modality(s).	- Control bleeding through direct pressure and tourniquet - Clean, close, and cover simple wounds - *Incise, drain, and pack abscess - *Perform pericardiocentesis - *Perform needle decompression of chest - Dispense, administer, and track *medications for control of pain and bleeding (injectable) - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation)
Medical Imaging	Imaging the body as an aid in making a medical diagnosis in a time-independent fashion based on images obtained.	- *Capability to image the human body (bones, vessels, organs, soft tissue) with at least one standard medical imaging modality
Dental Care	Provide temporizing maneuvers to manage dental pain until definitive care is reached.	- Dispense, administer, and track medications for dental care (oral, topical, injectable) - Ability to cover fractured tooth with dental material. - Incise dental abscess

		- Manage oral secretions during examination and procedures - *Extract teeth

Level of Care V

NASA-STD-3001, Vol 1, describes Level of Care V as follows: "A high level of potential risk exists that personnel may experience medical problems on orbit at some time during the mission. Preventive strategies shall be used to a greater degree to reduce the overall risk. The ability to support chronic illness is limited. Intervention strategies shall be used to reduce the risk to an acceptable level, including increasing levels of autonomous advanced care in the form of medications, equipment, training, or consumables over and above those for previous levels. The training and skill of the caregiver shall be at the physician level, because of the exclusively autonomous nature of the mission. The scope of medical care available shall be limited or triaged because of availability of supplies, consumables, or mission risk. Return to Earth is not a viable option for more serious illness/injuries. Impact to overall mission is greater."

The definition and example actions ExMC has chosen in order to examine the differences between the capabilities are listed below in Table 6.

Table 6 - Level of Care V Interpretation

Capability	Definition	Example Actions
Level of Care IV +		"*" indicates augmentation of action from lower level of care
Autonomous Ambulatory Care	Diagnosis, treatment, and rehabilitation, where necessary, for non-urgent and urgent medical, traumatic, and psychological conditions. The autonomous nature of this care indicates that it can be completed without the use of ground resources; the limits of autonomous care will be condition-specific. Resources to support time-independent medical decision making using data obtained from physical exam, vital signs, clinical diagnostics, and medical imaging modality(s).	- Measure, record and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation) - Perform *full physical exam (visualize, palpate, auscultate) and record results - *Supplement physical exam using available clinical diagnostics and medical imaging - Dispense, administer, and track medications *used in diagnosis, treatment, and rehabilitation for urgent and non-urgent medical and traumatic conditions including dental issues (oral, topical, inhaled, injectable) - Splint extremities - Drain bladder (continuous/intermittent) - Ability to cover fractured tooth with dental material - *Remove decayed material from tooth in preparation for repair - Replace lost filling or crown - Incise dental abscess - Manage oral secretions during examination and procedures - Extract teeth - *Perform psychological exam and counselling
Autonomous Advanced Life Support	Diagnosis and critical care treatment for an emergent medical or traumatic event using medical information obtained from physical exam, clinical diagnostics, and medical imaging.	- Recognize need for increased level of care - Control over body positioning and workspace **Airway:** - Reposition airway, insert airway adjuncts, supraglottic, endotracheal, *and surgical airways - Clear obstructed airway with manual maneuvers - Suction airway and decompress stomach **Breathing:** - Provide breaths using manual and automated means - Provide and titrate oxygen via noninvasive/invasive means

	Rehabilitation and palliative care options will be provided. The autonomous nature of this care indicates that initial stabilization maneuvers can be completed without the use of ground resources; the limits of autonomous care will be condition-specific. Resources to support time-independent medical decision making using data obtained from physical exam, vital signs, clinical diagnostics, and medical imaging modality(s).	- Perform needle decompression of chest **Circulation:** - Control bleeding using direct pressure - Provide chest compressions - Electrocardiogram (ECG) rhythm diagnosis - Defibrillate, *synch cardiovert, and pace using manually operated device. - Provide intravenous (IV) or intraosseous (IO) access and fluids - Dispense, administer, and track medications *used to treat an intubated critical care patient (oral, topical, injectable, inhaled) - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation, *end tidal carbon dioxide (ETCO2) - Drain bladder (continuous/intermittent)
Autonomous Basic Surgical Care	Any invasive operative procedure less than one hour in duration requiring only local/regional anesthesia or moderate sedation. The autonomous nature of this care indicates that this care can be completed without the use of ground resources; the limits of autonomous care will be condition-specific. Resources to support time-independent medical decision making using data obtained from physical exam, vital signs, clinical diagnostics, and medical imaging modality(s).	- Control over body positioning and workspace **Airway:** - Reposition airway, insert airway adjuncts, supraglottic, endotracheal, and *surgical airways - Clear obstructed airway with manual maneuvers - Suction airway and decompress stomach **Breathing:** - Provide breaths using manual and automated means - Provide and titrate oxygen via noninvasive/invasive means - Perform needle decompression of chest - *Place chest tube, connect to suction **Circulation:** - Control bleeding using direct pressure, tourniquet, and wound closure (simple + complex) - Splint extremities - Provide chest compressions - Perform pericardiocentesis - ECG rhythm diagnosis - Defibrillate, *synch cardiovert, and pace using manually operated device. - Provide intravenous (IV) or intraosseous (IO) access and fluids - Dispense, administer, and track medications* used to treat an intubated trauma patient including local, regional anesthesia, and moderate sedation (oral, topical, injectable, inhaled) - Perform secondary & tertiary survey - Measure, record, and trend vital signs (heart rate & rhythm, respiratory rate, blood pressure, temperature, oxygen saturation, end tidal carbon dioxide (ETCO2) - Incise, drain, and pack abscess - Clean, close, and cover wounds (simple & complex) - Drain bladder (continuous/intermittent)

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